Surgical Anatomy and Bifurcation Patterns of the Popliteal Artery: An Anatomical Study

A. Poplitea'nın Cerrahi Anatomisi ve Dallanma Şekilleri: Anatomik Bir Çalışma

Çağatay BARUT, MD,[a]
Özdemir SEVİNÇ, MD,[b]
Hilmi ÖZDEN, MD,[c]
Ayhan CÖMERT, MD,[d]
Ali Fırat ESMER, MD,[d]
İbrahim TEKDEMİR, MD,[d]
Alaittin ELHAN,[d]

Department of Anatomy,
[a]Zonguldak Karaelmas University Faculty of Medicine, Zonguldak
[b]Düzce University School of Medicine, Düzce
[c]Eskişehir Osmangazi University Faculty of Medicine, Eskişehir
[d]Ankara University School of Medicine, Ankara

Geliş Tarihi/*Received:* 02.05.2008
Kabul Tarihi/*Accepted:* 08.09.2008

**This study was presented as a poster presentation in the 4th Asian Pacific International Congress of Anatomists, Kuşadası, Turkey, September 7-10, 2005.*

Yazışma Adresi/*Correspondence:*
Çagatay BARUT, MD,
Zonguldak Karaelmas University Faculty of Medicine,
Department of Anatomy, Zonguldak, TÜRKİYE/TURKEY
cagbarut@yahoo.com

ABSTRACT Objective: To clarify the anatomy of the popliteal artery and to determine key variations in the bifurcation patterns of the popliteal artery. **Material and Methods:** The popliteal fossae of 28 (12 right and 16 left) fixed lower extremities were carefully dissected, and the arterial pattern from the distal edge of the adductor hiatus (AH) to the proximal portion of each leg was documented. A digital caliper was used to measure the arterial length. The transverse plane between the distal edges of the femoral condyles (FCs), which is easily located, was used as reference. **Results:** The mean length of the popliteal artery (PA) from the AH to the FCs was 9.26 ± 1.63 cm on the right side and 10.08 ± 2.12 cm on the left side, while the mean distance from the FCs to the site of bifurcation into the anterior and posterior tibial arteries was 7.20 ± 1.98 cm on the right side and 6.69 ± 1.15 cm on the left. The average arterial length from the level of the FCs to the site of origin of the peroneal artery was 10.01 ± 1.78 cm on the right side and 9.18 ± 1.07 cm on the left side, and the PA/extremity ratio was 0.21 ± 0.04 on the right side and 0.22 ± 0.04 on the left. Variable patterns of adult popliteal artery termination were observed. **Conclusion:** The data presented here can help reduce the complication rate and improve the success rate of both urgent and elective vascular procedures, which often require exposure of the popliteal artery.

Key Words: Popliteal artery; anatomy; cadaver

ÖZET Amaç: A. poplitea anatomisini ve dallanma yapısındaki önemli farklılıkları ortaya koymak. **Gereç ve Yöntemler:** 28 (12 sağ, 16 sol) fikse edilmiş alt ekstremitede fossa poplitea disseksiyonu yapıldı ve hiatus adductorius'un (AH) distal bölümü ile bacağın proksimal bölümü arasındaki arteriyel yapılanma incelendi. Arter uzunluklarını ölçmek için dijital bir kumpas kullanıldı. Femur'un condylus medialis ve condylus lateralis'ini birleştiren transvers düzlem (FC) referans olarak kullanıldı. **Bulgular:** AH ile FC arasında ortalama a. poplitea uzunluğu sağ tarafta 9.26 ± 1.63 cm, sol tarafta 10.08 ± 2.12 cm olarak ölçüldü. FC hattından a. tibialis anterior ve a. tibialis posterior'un dallanma bölgesine olan uzunluk sağda 7.20 ± 1.98 cm, solda 6.69 ± 1.15 cm olarak ölçüldü. FC hattından a. peronea'nın ayrılma yerine kadar olan mesafe sağda 10.01 ± 1.78 cm, solda 9.18 ± 1.07 cm olarak ölçüldü. A. poplitea/ekstremite oranı sağ tarafta 0.21 ± 0.04, sol tarafta 0.22 ± 0.04 olarak hesaplandı. A. poplitea'nın farklı şekillerde sonladığı gözlendi. **Sonuç:** Elde ettiğimiz sonuçların a. poplitea'yı ilgilendiren acil ve elektif şartlardaki cerrahi girişimlerde komplikasyonların azaltılmasına ve başarı oranının arttırılmasına yardımcı olabileceği düşünüldü.

Anahtar Kelimeler: A. poplitea; anatomi; kadavra

Turkiye Klinikleri J Med Sci 2009;29(2):338-43

Injury to the popliteal artery can occur during knee surgery, which poses a major clinical problem as such injuries can lead to amputation.[1] In addition, aneurysms of the popliteal artery are the most common type of peripheral arterial aneurysm.[2] The soleus muscle flaps and posterior tib-

ial fasciocutaneous flaps can be used to cover and reconstruct soft tissue defects in the lower limbs; however, preoperative planning of femorodistal popliteal and tibial arterial reconstruction or of (other) emergency surgical procedures requires accurate information regarding the course of the popliteal artery and its branches.[3,4] Thus, it is necessary to clarify the anatomy of the popliteal artery, including key variations in its bifurcation pattern.

In classical textbooks, while the origin and branches of the popliteal artery are described with their adjacent structures, clear and detailed data regarding the branching patterns and distances of the genicular and other branches are lacking.[5] Several studies have examined the branching patterns and anatomy of the popliteal artery, with some of them using radiograms to classify and relate variant patterns of the popliteal artery.[1-4,6-10] In some cadaveric studies, only the branching pattern was investigated, while other studies used landmarks to describe the distances of the popliteal artery branches from the adductor hiatus (AH) and the distance to the bifurcation.[4,8,9] The preferred landmarks vary among different studies and include "the tip of the head of fibula", "a transverse plane through the middle of the knee joint at the level of the distal edge of the femoral condyles (FC)", the "medial tibial plateau", and "the level of the medial joint line".[4,7,9,11]

The aim of this study was to describe the normal anatomy and key variations in the bifurcation pattern of the popliteal artery.

MATERIAL AND METHODS

The popliteal fossae of 28 (12 right and 16 left) lower extremities fixed in 10% formalin were injected with colored latex and carefully dissected (in some regions with the aid of a Zeiss OPMI 9-FC surgical microscope) and the arterial pattern from the distal edge of the AH to the proximal portion of each leg was documented. A digital caliper with a resolution of 0.01 mm was used to measure the arterial length and external diameter of the arteries at their origins and at different levels (BTS Digital Caliper 150 × 0.01 mm). The transverse plane at the distal edge of the FC was used as a reference since it can easily be located from the surface in the lower extremities. Mean values, maximum and minimum values, and standard deviations were calculated for all cases using SPSS for Windows (release 11.01).

Measured lengths of the popliteal artery include

PA1: Popliteal artery from the AH to the FC (AH-FC);

PA2: Popliteal artery from the FC to the site of bifurcation into the anterior tibial artery and tibioperoneal trunk (terminal bifurcation point, TBP) (FC-TBP); and

FC-PeA: Artery from the level of the FC to the site of origin of the peroneal artery (PeA).

These measurements were added to obtain

PA (PA1 + PA2): The total length of the popliteal artery from the AH to the TBP; and

AH-PeA: The distance from the AH to the point of origin of the PeA.

The mean diameters of the following arteries were measured:

DPA (AH): Popliteal artery at the AH;

DPA (FC): Popliteal artery at the level of FC;

DATA: Anterior tibial artery at its site of origin;

DPTA: Posterior tibial artery at its origin; and

DPeA: Peroneal artery at its origin.

The distances of the genicular arteries from the AH were also measured:

AH-SLGA: The distance from the AH to the superior lateral genicular artery;

AH-SMGA: The distance from the AH to the superior medial genicular artery;

AH-ILGA: The distance from the AH to the inferior lateral genicular artery;

AH-IMGA: The distance from the AH to the inferior medial genicular artery; and

AH-MGA: The distance from the AH to the middle genicular artery.

The distance between the anterior superior iliac spine and medial malleolus (ASIS-MM) of each lower limb lying parallel to the median plane in the supine position was measured to calculate the standardized PA/ASIS-MM ratio, which is referred to as PA/extremity. A digital caliper with a resolution of 0.01 mm (BTS Digital Caliper 500 × 0.01 mm) was used to measure ASIS-MM.

RESULTS

Length and diameter measurements were made for 28 lower extremities (12 right and 16 left). The mean length of the popliteal artery from the AH to the FC was 9.26 ± 1.63 cm on the right side and 10.08 ± 2.12 cm on the left side and the mean distance from the FC to the site of bifurcation into the anterior and posterior tibial arteries was 7.20 ± 1.98 cm on the right side and 6.69 ± 1.15 cm on the left. The average arterial length from the FC to the site of origin of the peroneal artery was 10.01 ± 1.78 cm on the right side and 9.18 ± 1.07 cm on the left side. The length ratio of the popliteal artery to the total extremity was 0.21 ± 0.04 on the right side and 0.22 ± 0.04 on the left. The ratio of the AH-PeA to the total extremity length was 0.24 ± 0.04 on the right side and 0.25 ± 0.04 on the left (Table 1). A comprehensive list of our results was shown in Table 1. Figure 1 and 2 show the details of the branching pattern of the popliteal artery.

Notably, we encountered one case of a trifurcation at the termination site of the popliteal artery that divided into the anterior tibial, posterior tibial, and peroneal arteries; the distance between the AH and the trifurcation site was 18.70 cm.

TABLE 1: Measurements of the popliteal artery (cm)

	Right (n= 12)				Left (n= 16)				Overall (n= 28)			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
ASIS-MM	73.00	84.00	78.77	3.53	71.00	85.00	77.50	4.44	71.00	85.00	77.97	4.07
PA1: AH-FC	6.70	11.50	9.26	1.63	7.50	14.30	10.08	2.12	6.70	14.30	9.76	1.94
PA2: FC-TBP	4.30	10.10	7.20	1.98	5.30	9.20	6.69	1.15	4.30	10.10	6.90	1.51
FC-PeA	7.90	13.50	10.01	1.78	7.00	11.10	9.18	1.07	7.00	13.50	9.51	1.42
AH-SLGA	1.90	7.50	4.63	2.28	3.00	8.60	6.13	1.78	1.90	8.60	5.53	2.08
AH-SMGA	2.60	6.90	4.63	1.59	1.50	10.10	5.59	2.33	1.50	10.10	5.21	2.08
AH-MGA	3.80	10.30	8.17	2.62	2.60	11.10	7.27	2.92	2.60	11.10	7.63	2.74
AH-ILGA	6.50	12.90	10.46	2.74	5.40	13.80	9.92	2.66	5.40	13.80	10.14	2.63
AH-IMGA	7.00	12.60	10.49	2.53	5.10	14.60	10.24	2.97	5.10	14.60	10.34	2.72
AH-SAA	10.90	11.90	11.40	0.71	9.70	13.30	10.90	1.66	9.70	13.30	11.07	1.35
FC-ASLG	2.50	7.10	4.64	1.43	1.60	6.40	3.95	1.42	1.60	7.10	4.23	1.42
FC-ASMG	3.70	6.00	4.64	0.77	1.90	8.50	4.49	2.11	1.90	8.50	4.55	1.67
FC-AMG	-.90	3.20	1.47	1.63	.20	7.40	3.08	2.42	-0.90	7.40	2.43	2.23
FC-AILG	-4.60	1.50	-1.20	2.04	-3.30	2.20	0.17	1.78	-4.60	2.20	-0.38	1.96
FC-AIMG	-4.10	1.10	-1.23	1.84	-1.70	2.40	-.06	1.27	-4.10	2.40	-0.55	1.60
FC-AAS	-2.80	-0.40	-1.60	1.70	-1.60	4.40	0.96	2.55	-2.80	4.40	0.12	2.50
DPA(AH)	0.42	0.73	0.58	0.12	0.48	0.80	0.63	0.09	0.42	0.80	0.61	0.10
DPA (FC)	0.33	0.64	0.50	0.12	0.42	0.68	0.53	0.07	0.33	0.68	0.52	0.09
DATA	0.20	0.47	0.35	0.10	0.22	0.48	0.37	0.09	0.20	0.48	0.36	0.09
DPTA	0.33	0.52	0.41	0.07	0.24	0.54	0.40	0.09	0.24	0.54	0.40	0.08
DPeA	0.20	0.42	0.30	0.07	0.20	0.42	0.32	0.06	0.20	0.42	0.31	0.07
PA (PA1+PA2)	11.00	19.50	16.46	3.18	13.20	22.10	16.78	2.85	11.00	22.10	16.65	2.91
PA/Extremity	0.13	0.25	0.21	0.04	0.16	0.29	0.22	0.04	0.13	0.29	0.21	0.04
PA-AH/TBP	.93	1.61	1.34	0.27	1.17	2.16	1.52	0.30	0.93	2.16	1.45	0.30
AH-PeA	14.70	22.90	19.28	2.95	14.50	24.00	19.26	2.83	14.50	24.00	19.27	2.80
AH-PeA/ Extremity	0.18	0.29	0.24	0.04	0.17	0.31	0.25	0.04	0.17	0.31	0.25	0.04

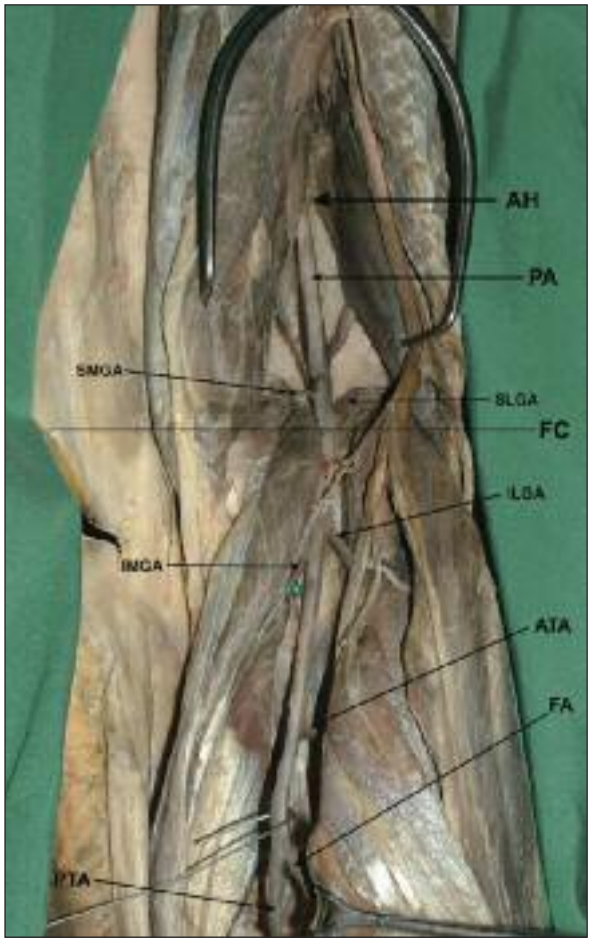

FIGURE 1: Overview of the popliteal artery and the TBP with reference to the FC.
TBP: Terminal bifurcation point; FC: Transverse plane between the distal edges of the femoral condyles; AH: Adductor hiatus; PA: Popliteal artery; SMGA: Superior medial genicular artery; SLGA: Superior lateral genicular artery; ILGA: Inferior lateral genicular artery; IMGA: Inferior medial genicular artery; ATA: Anterior tibial artery; FA: Peroneal artery; PTA: Posteror tibial artery

In addition, one of the popliteal arteries we dissected bifurcated into its terminal branches 4.3 cm below the level of the FC, and may be considered a high takeoff popliteal artery.

None of the popliteal arteries we dissected coursed deep to the popliteus muscle.

DISCUSSION

Our results were consistently smaller than those of Cross et al, which may be attributed to racial or individual morphological differences (Table 2).[9] Indeed, Cross et al neither included that type of information in their study nor reported the lengths of the lower extremities used.[9] To eliminate differences arising from individual features, we measured the SIAS-MM distance and calculated the aforementioned ratios.

Although our landmarks were different from those used by Schmeiser et al, the values recorded for SLGA, SMGA, ILGA, and IMGA were similar. The differences in MGA and SAA were likely due to the high variation rate of these structures.[11]

Although our analysis differed considerably from those of Raveendran and Kumagara and Tobin in terms of the approximate distance between landmarks, the average bifurcation distance of the PA (TBP) and the PeA distal to the fibular head or FC reported in our study were comparable.[4,12]

An evaluation of 147 arteriograms by Sanders and Alston revealed that the TBP of the popliteal artery was 6-8 cm in 91% of the limbs.[6] Despite the fact that our landmark was at the level of the FC

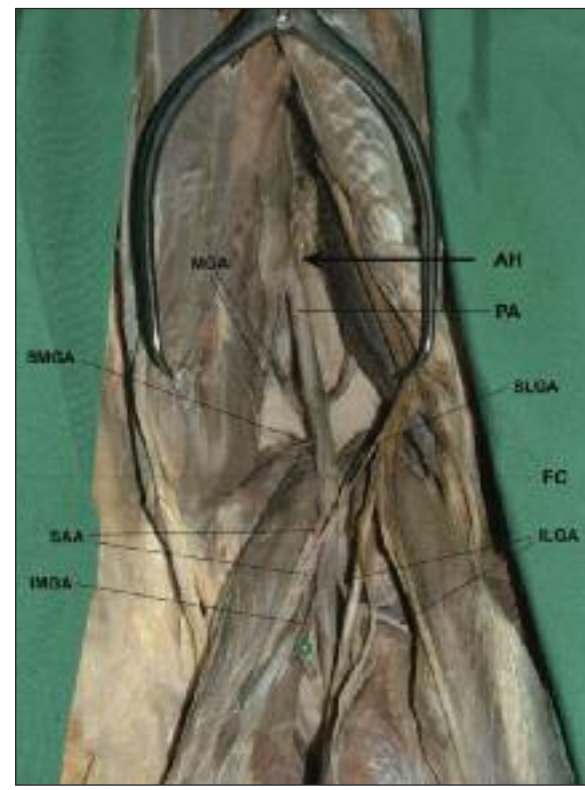

FIGURE 2: Genicular branching pattern of the popliteal artery with reference to the FC.
FC: Transverse plane between the distal edges of the femoral condyles; AH: Adductor hiatus; PA: Popliteal artery; SMGA: Superior medial genicular artery; SLGA: Superior lateral genicular artery; ILGA: Inferior lateral genicular artery; IMGA: Inferior medial genicular artery; MGA: Middle genicular artery; SAA: Sural arteries.

TABLE 2: Comparison of the diameters and lengths of the popliteal artery (cm).

	Cross et al[6]		Our study	
	Mean	SD	Mean	SD
PA1: AH-FC	14.0	2.1	9.76	1.94
PA2: FC-TBP	6.2	0.8	6.90	1.51
FC-PeA	9.1	1.9	9.51	1.42
DPA(AH) *	1.05*	0.22*	0.61	0.10
DPA (FC)	0.87	0.16	0.52	0.09
DATA	0.58	0.11	0.36	0.09
DPTA	0.47	0.01	0.40	0.08
DPeA	0.46	0.09	0.31	0.07
PA (PA1+PA2)	20.2	2.6	16.65	2.91
AH-PeA	23.1	3.3	19.27	2.80

*Popliteal-5 cm distal to AH.

and possible differences between angiographic and cadaveric studies depending on the techniques used, we believe that our results (FC-TBP: 6.90 ± 1.51) are in accordance with theirs (Table 1).

Although in classical anatomy textbooks, the terminal branches of the popliteal artery are shown to be the anterior and posterior tibial arteries, the usual branching pattern of the popliteal artery was determined to be the anterior tibial artery (ATA) and tibioperoneal artery by Kim et al and Day and Orme and the term tibioperoneal artery has gained wide acceptance in clinical practice.[2,5-7,13,14] Our observations on the typical branching pattern of the popliteal artery were in accordance with results cited in the literature.[2,7,14] Various landmarks of a similar nature have been used in several studies.[2,4,7,14] To avoid confusion, we relied on an easily recognizable landmark that can be readily utilized in clinical practice, thereby allowing the length of the popliteal artery and its branching points to be properly assessed during preoperative planning. Although Bardsley and Staple found no correlation between tibia length and the branching level of the popliteal artery, the ratios used in this study will be useful in preoperative and intraoperative planning for surgery in the popliteal region.[15] PA/extremity and PA-AH/TBP are important ratios to consider prior to surgery for individuals with unusual morphological traits. Measuring the lower extremity may also help predict the length of the popliteal artery and its branching points.

According to the literature, the diameter of the popliteal artery is related to age, body size, and sex, with males having larger arteries than females.[16] Sandgren et al reported that the diameter of the popliteal artery was 6.71 ± 0.91 mm and 8.41 ± 1.61 mm, respectively, in men and women with abdominal aortic aneurysms.[17] Although we did not evaluate gender differences in the current study, our results were not in accordance with these findings (Table 1). Differences in the measurement sites or the pathological condition of the study group may explain the discrepancy.

Knowledge of the normal anatomical characteristics of the popliteal artery and its relationship with the FC, which is an easily located landmark, can be useful for anatomists and surgeons performing procedures in that region. It is evident that when a variation is detected, the standard approach may require modification. In addition, the data presented in this paper may be helpful for the placement of retractors or in the use of oscillating saws and osteotomes during surgery to prevent complications.

REFERENCES

1. Ninomiya JT, Dean JC, Goldberg VM. Injury to the popliteal artery and its anatomic location in total knee arthroplasty. J Arthroplasty 1999;14(7):803-9.
2. Colborn GL, Lumsden AB, Taylor BS, Skandalakis JE. The surgical anatomy of the popliteal artery. Am Surg 1994;60(4):238-46.
3. Wu WC, Chang YP, So YC, Yip SF, Lam YL. The anatomic basis and clinical applications of flaps based on the posterior tibial vessels. Br J Plast Surg 1993;46(6):470-9.
4. Raveendran SS, Kumaragama KG. Arterial supply of the soleus muscle: anatomical study of fifty lower limbs. Clin Anat 2003;16(3):248-52.
5. Moore KL, Dalley AF. Clinically Oriented Anatomy. 4th ed. Philadelphia: Lippincott Williams and Wilkins; 1999. p.571-5.
6. Sanders RJ, Alston GK. Variations and anomalies of the popliteal and tibial arteries. Am J Surg 1986;152(5):531-4.
7. Kim D, Orron DE, Skillman JJ. Surgical significance of popliteal arterial variants. A unified angiographic classification. Ann Surg 1989;210(6):776-81.
8. Piral T, Germain M, Princ G. Absence of the posterior tibial artery: implications for free transplants of the fibula. Surg Radiol Anat 1996;18(2):155-8.
9. Cross L, Hall J, Howdieshell TR, Colborn GL, Gale TF. Clinical anatomy of the popliteal blood vessels. Clin Anat 2000;13(5):347-53.

10. Trigaux JP, Van Beers B, De Wispelaere JF. Anatomic relationship between the popliteal artery and vein: a guide to accurate angiographic puncture. AJR Am J Roentgenol 1991;157(6):1259-62.
11. Schmeiser G, Hempfling H, Bühren V, Putz R. The popliteal region: an anatomical study and a new approach to the tibial attachment of the posterior cruciate ligament. Surg Radiol Anat 2001;23(1):9-14.
12. Tobin GR. Hemisoleus and reversed hemisoleus flaps. Plast Reconstr Surg 1985;76(1):87-96.
13. Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 39th ed. Edinburgh: Elsevier Churchill Livingstone; 2005. p.1486.
14. Day CP, Orme R. Popliteal artery branching patterns -- an angiographic study. Clin Radiol 2006;61(8):696-9.
15. Bardsley JL, Staple TW. Variations in branching of the popliteal artery. Radiology 1970;94(3):581-7.
16. Sandgren T, Sonesson B, Ahlgren AR, Länne T. Factors predicting the diameter of the popliteal artery in healthy humans. J Vasc Surg 1998;28(2):284-9.
17. Sandgren T, Sonesson B, Ryden-Ahlgren, Länne T. Arterial dimensions in the lower extremities of patients with abdominal aortic aneurysms--no indications of a generalized dilating diathesis. J Vasc Surg 2001;34(6): 1079-84.